

US008360040B2

(12) **United States Patent**
Stewart et al.

(10) **Patent No.:** **US 8,360,040 B2**
(45) **Date of Patent:** **Jan. 29, 2013**

(54) **ENGINE CONTROLLER**
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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.
(21) Appl. No.: **13/353,178**

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(22) Filed: **Jan. 18, 2012**

(65) **Prior Publication Data**
US 2012/0116649 A1 May 10, 2012

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Related U.S. Application Data

(63) Continuation of application No. 12/973,704, filed on Dec. 20, 2010, now Pat. No. 8,109,255, which is a continuation of application No. 12/144,445, filed on Jun. 23, 2008, now Pat. No. 7,878,178, which is a continuation of application No. 11/206,404, filed on Aug. 18, 2005, now Pat. No. 7,389,773.

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(51) **Int. Cl.**
F02D 41/00 (2006.01)
(52) **U.S. Cl.** **123/672**; 701/104; 701/105
(58) **Field of Classification Search** 701/103–106, 701/109; 123/672, 673, 691, 435, 472, 478, 123/479, 480, 299, 300, 305, 456, 457; 60/285, 60/286

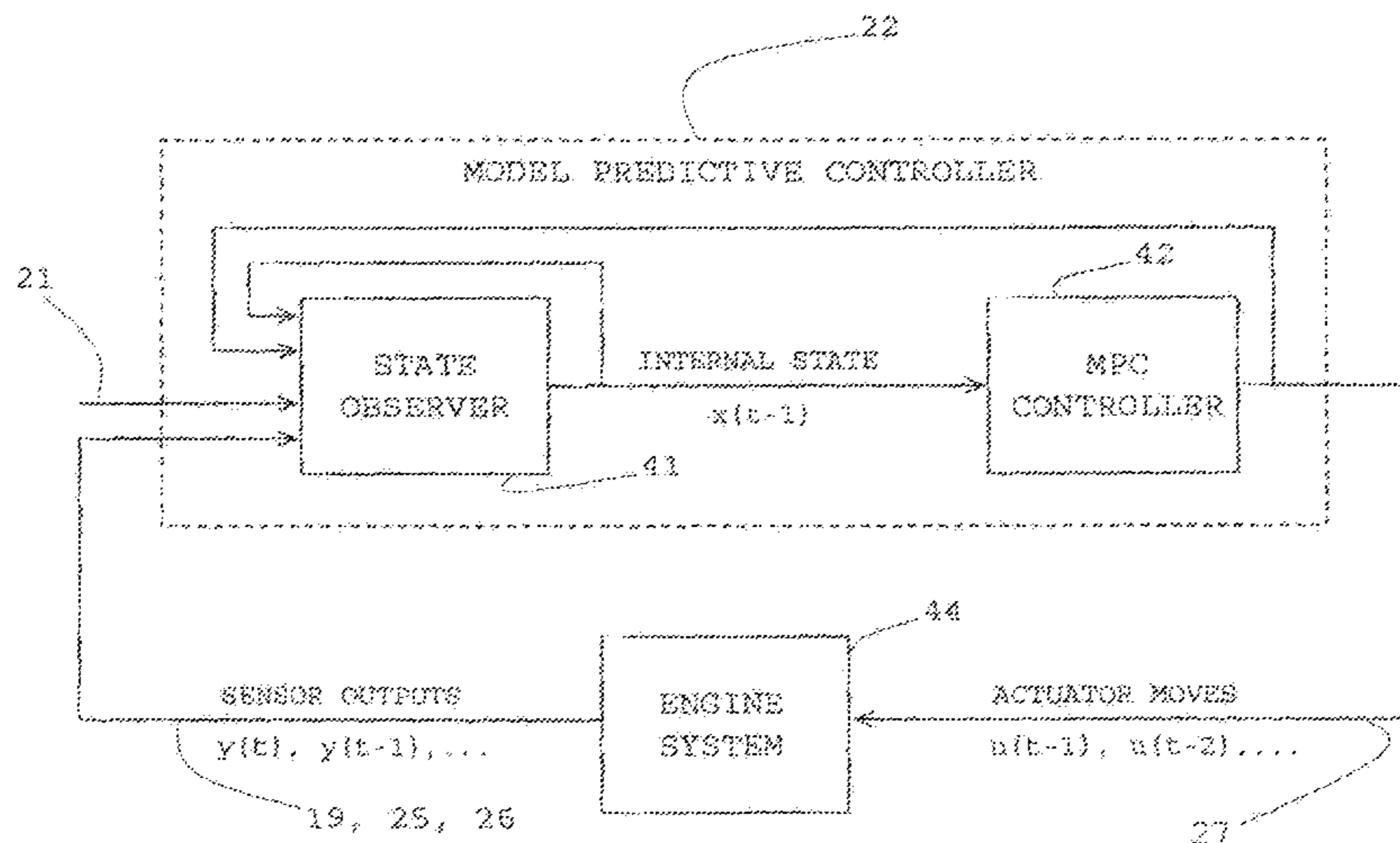
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See application file for complete search history.

(57) **ABSTRACT**
A system for controlling fuel to an engine to minimize emissions in an exhaust of the engine. There may be a controller connected to an actuator, for example a fuel control actuator, of the engine and to emissions sensors, such as an NOx and/or PM sensor, proximate to an exhaust output of the engine. The controller, for example a speed controller, may have an input connected to an output of a pedal or desired speed setting mechanism. A speed sensor at a power output of the engine may be connected to an input of the controller.

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20 Claims, 5 Drawing Sheets



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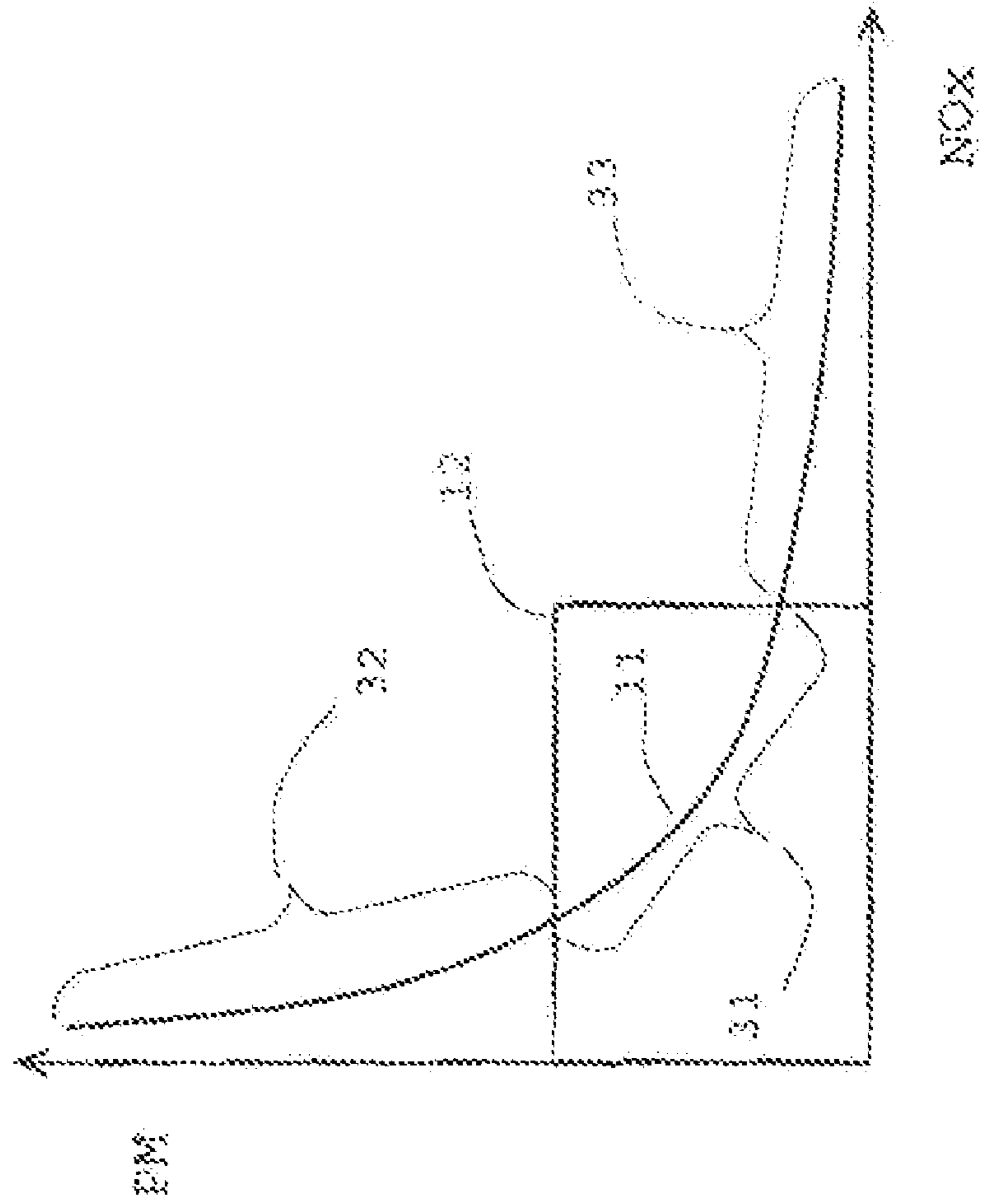


FIGURE 1

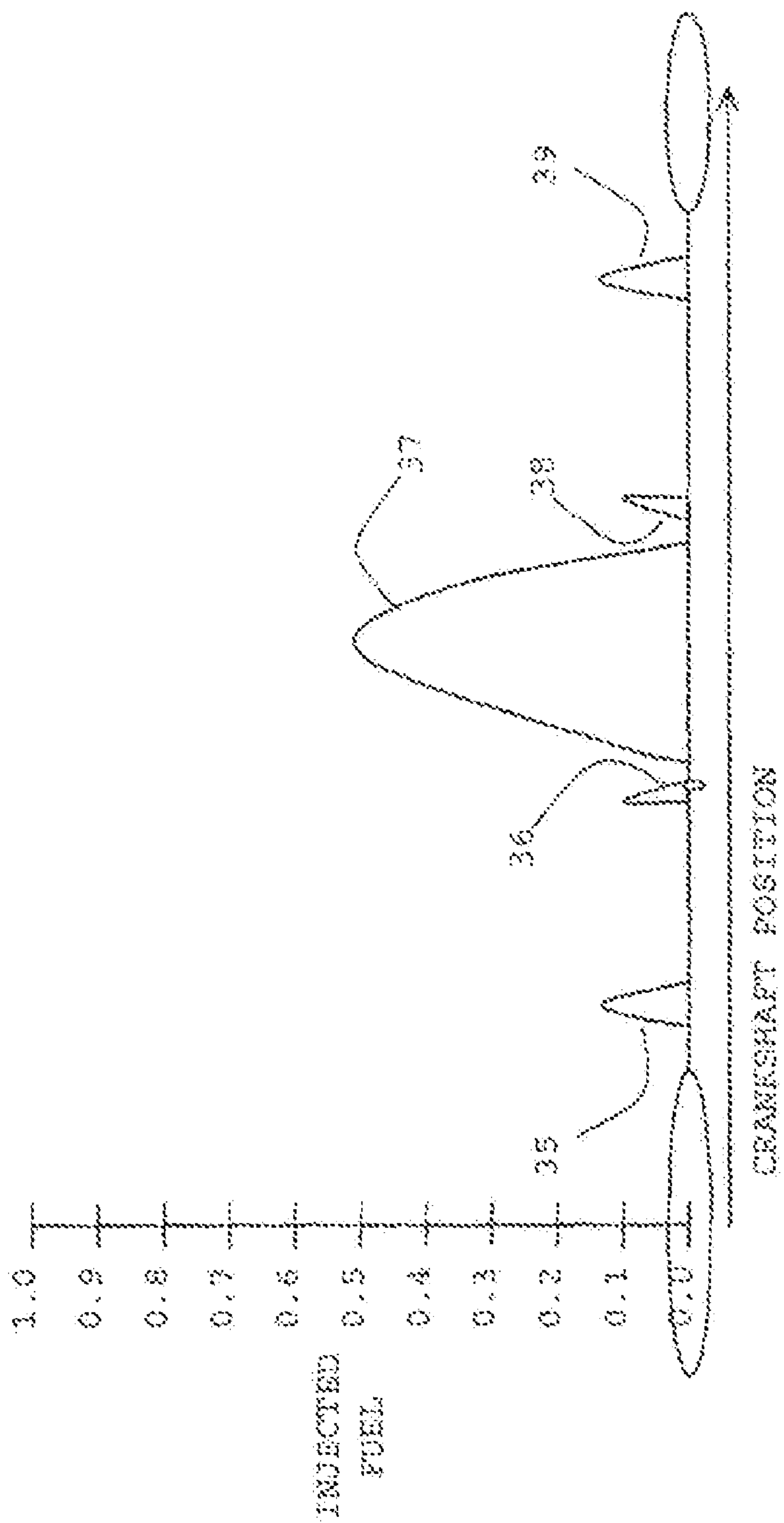


FIGURE 2

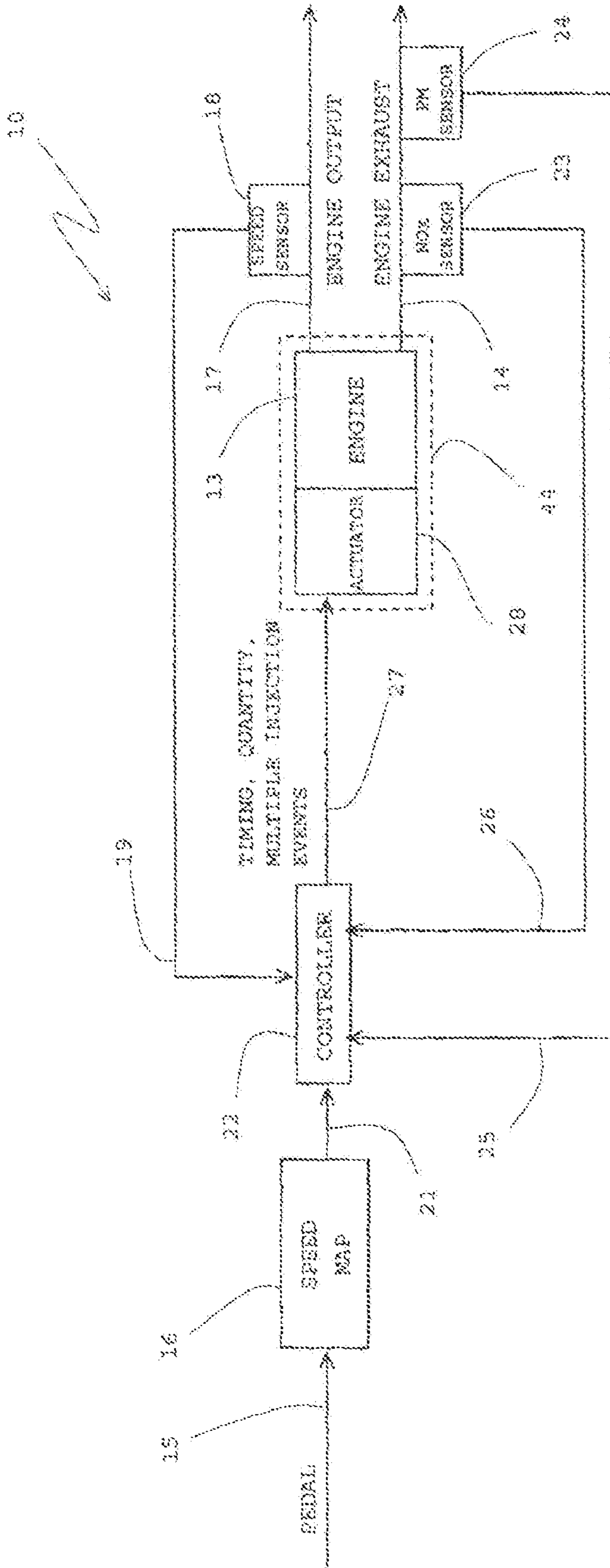


FIGURE 3

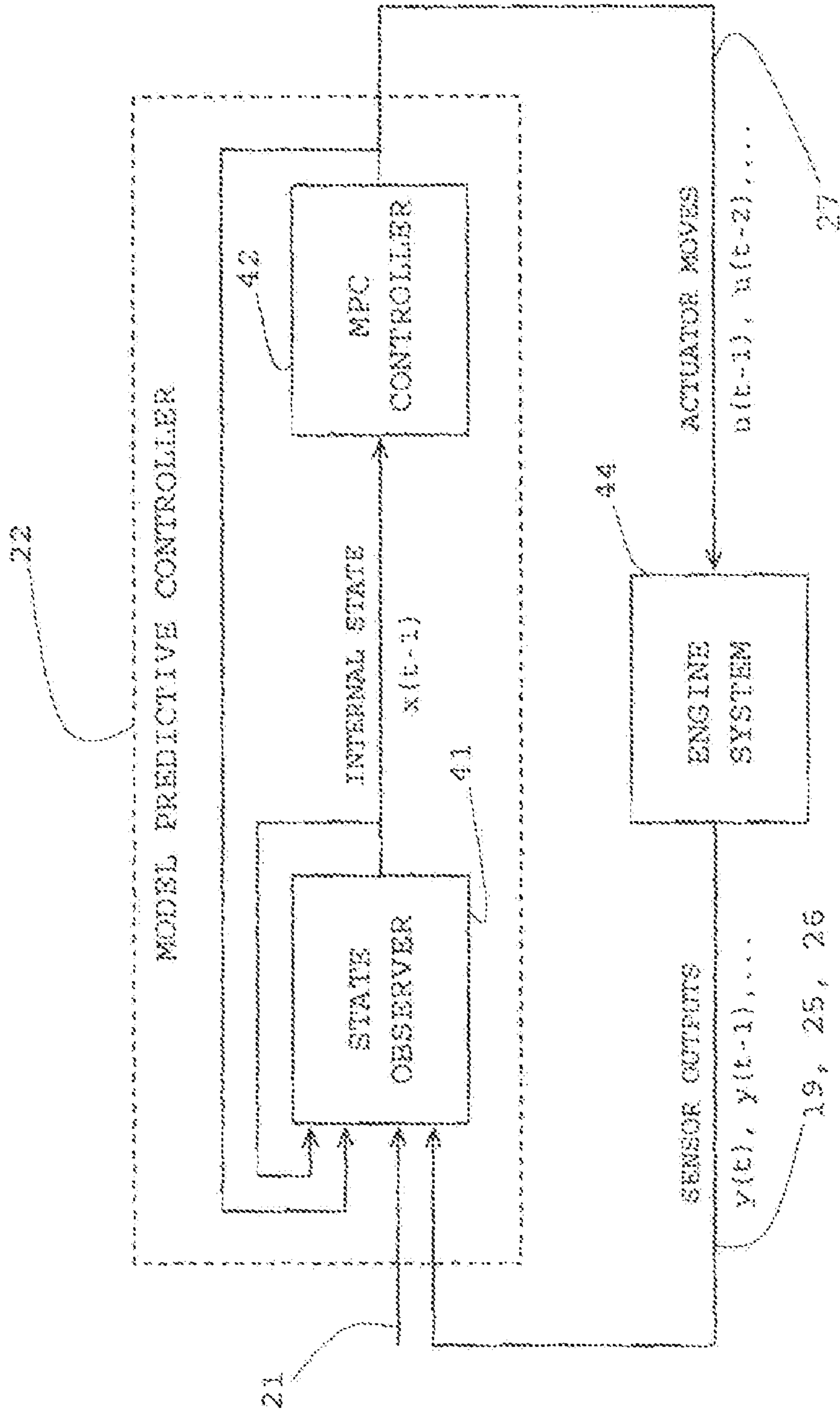


FIGURE 4

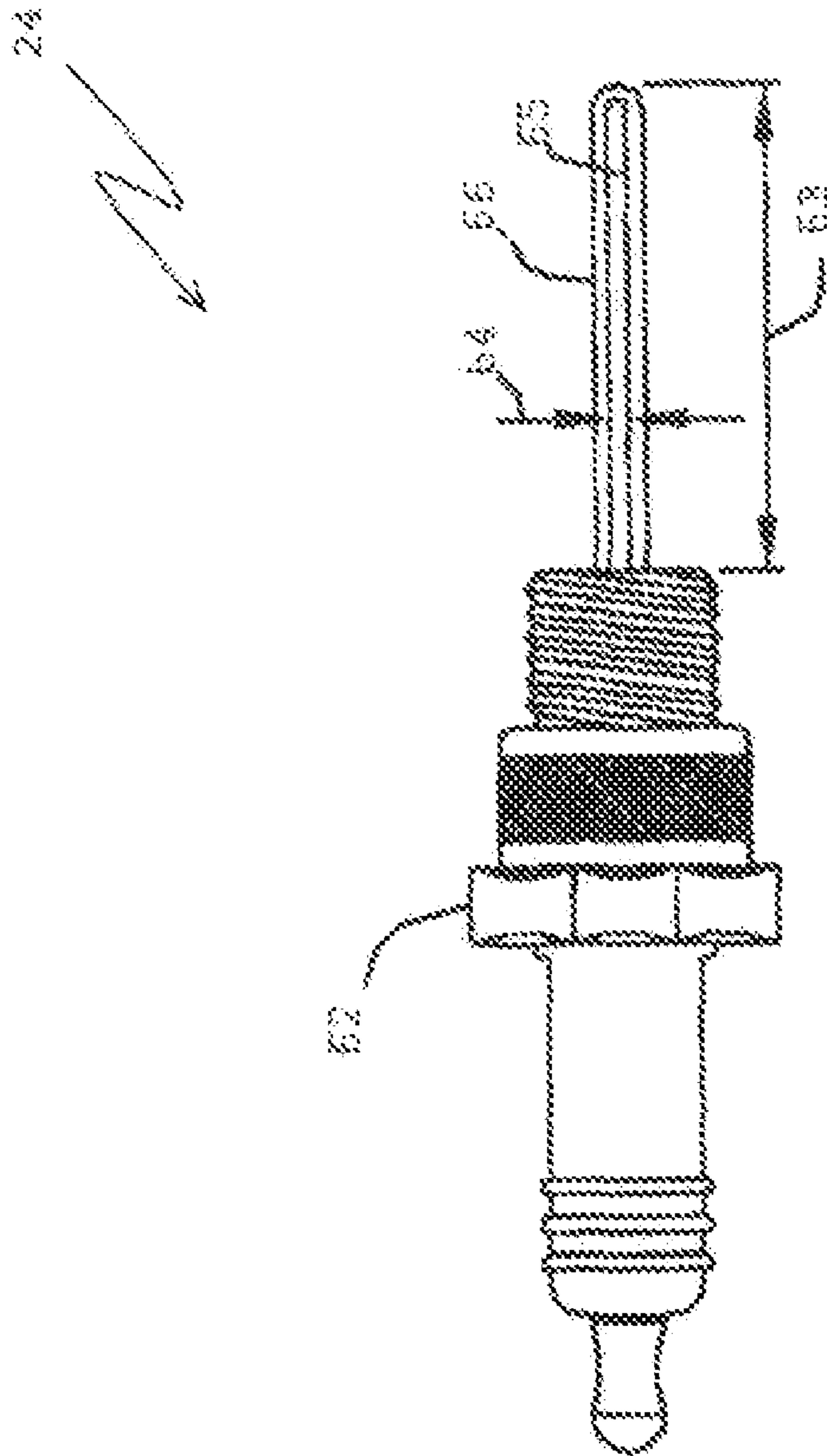


FIGURE 5

ENGINE CONTROLLER

This application is a continuation of U.S. application Ser. No. 12/973,704, filed Dec. 20, 2010, entitled, "ENGINE CONTROLLER", which is a continuation of U.S. application Ser. No. 12/144,445 filed Jun. 23, 2008, entitled, "EMISSIONS SENSORS FOR FUEL CONTROL IN ENGINES", now U.S. Pat. No. 7,878,178, which is a continuation of U.S. application Ser. No. 11/206,404 filed Aug. 18, 2005, entitled, "EMISSIONS SENSORS FOR FUEL CONTROL IN ENGINES", now U.S. Pat. No. 7,389,773.

BACKGROUND

The present invention pertains to engines and particularly to fuel control for internal combustion engines. More particularly, the invention pertains to fuel control based on contents of engine exhaust.

SUMMARY

The present invention includes fuel control of an engine based on emissions in the exhaust gases of the engine.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a chart showing the standard diesel engine tradeoff between particulate matter and nitrogen oxide emissions of an engine;

FIG. 2 is a graph of fuel injector events and the magnitudes reflecting some injection rate control for an engine;

FIG. 3 is a diagram of an emission sensing and control system for engine fuel control;

FIG. 4 is a schematic view of an illustrative model predictive controller; and

FIG. 5 shows a particulate matter sensor.

DESCRIPTION

Engines often use catalytic converters and oxygen sensors to help control engine emissions. A driver-commanded pedal is typically connected to a throttle that meters air into engine. That is, stepping on the pedal directly opens the throttle to allow more air into the engine. Oxygen sensors are often used to measure the oxygen level of the engine exhaust, and provide feed back to a fuel injector control to maintain the desired air/fuel ratio (AFR), typically close to a stoichiometric air-fuel ratio to achieve stoichiometric combustion. Stoichiometric combustion can allow three-way catalysts to simultaneously remove hydrocarbons, carbon monoxide, and oxides of nitrogen (NOx) in attempt to meet emission requirements for the spark ignition engines.

Compression ignition engines (e.g., diesel engines) have been steadily growing in popularity. Once reserved for the commercial vehicle markets, diesel engines are now making real headway into the car and light truck markets. Partly because of this, federal regulations were passed requiring decreased emissions in diesel engines.

Many diesel engines now employ turbochargers for increased efficiency. In such systems, and unlike most spark ignition engines, the pedal is not directly connected to a throttle that meters air into engine. Instead, a pedal position is used to control the fuel rate provided to the engine by adjusting a fuel "rack", which allows more or less fuel per fuel pump shot. The air to the engine is typically controlled by the turbocharger, often a variable nozzle turbocharger (VNT) or waste-gate turbocharger.

Traditional diesel engines can suffer from a mismatch between the air and fuel that is provided to the engine, particularly since there is often a time delay between when the operator moves the pedal, i.e., injecting more fuel, and when the turbocharger spins-up to provide the additional air required to produced the desired air-fuel ratio. To shorten this "turbo-lag", a pedal position sensor (fuel rate sensor) may be added and fed back to the turbocharger controller to increase the natural turbo acceleration, and consequently the air flow to the engine which may for example set the vane positions of a VNT turbocharger.

The pedal position is often used as an input to a static map, the output of which is in turn used as a setpoint in the fuel injector control loop which may compare the engine speed setpoint to the measured engine speed. Stepping on the pedal increases the engine speed setpoint in a manner dictated by the static map. In some cases, the diesel engine contains an air-fuel ratio (AFR) estimator, which is based on input parameters such as fuel injector flow and intake manifold air flow, to estimate when the AFR is low enough to expect smoke to appear in the exhaust, at which point the fuel flow is reduced. The airflow is often managed by the turbocharger, which provides an intake manifold pressure and an intake manifold flow rate for each driving condition.

In diesel engines, there are typically no sensors in the exhaust stream analogous to the oxygen sensors found in spark ignition engines. Thus, control over the combustion is often performed in an "open-loop" manner, which often relies on engine maps to generate set points for the intake manifold parameters that are favorable for acceptable exhaust emissions. As such, engine air-side control is often an important part of overall engine performance and in meeting exhaust emission requirements. In many cases, control of the turbocharger and EGR systems are the primary components in controlling the emission levels of a diesel engine.

Diesel automotive emissions standards today and in the future may be partly stated in terms of particulate matter (soot) and nitrogen oxides (NOx). Direct measurement feedback on the true soot measurement may have significant advantages over an air-fuel ratio (AFR) in the related art. The present system may enable one to read the soot directly rather than using an (unreliable) AFR estimation to infer potential smoke. Particulate matter (PM) and NOx sensor readings may be used for fuel injection control in diesel engines. The NOx and PM may both be regulated emissions for diesel engines. Reduction of both NOx and PM would be favorable. There may be a fundamental tradeoff between NOx and PM such that for most changes made to a diesel engine, reducing the engine-out PM is typically accompanied by an increase in engine-out NOx and vice versa. In FIG. 1, the abscissa indicates a magnitude of PM and the ordinate indicates a magnitude of NOx in an engine exhaust gas. An engine's PM and NOx emissions may be indicated with a curve 11. An area 12 represents the maximum emissions for an engine exhaust gas. A PM sensor may be good for characterizing the PM part of the curve 11 (typically associated with a rich combustion, high exhaust gas recirculation (EGR) rates, or otherwise). A NOx sensor may be well suited to characterize the "other extreme" of curve 11 representing a diesel engine combustion (typically associated with lean, hot burn, low EGR, and the like). The present invention may incorporate the notion that a diesel emissions control problem requires both ends of the diesel combustion to be covered by emissions sensing. NOx and PM sensors may give information that is synthesized into an understanding of the diesel combustion. This is important since both NOx and PM are increasingly tightly legislated emissions in many countries.

Some fuel injection handles or parameters may have certain impacts on NOx and PM emissions. Examples may include an early start of the injection which may result in good brake specific fuel consumption (bsfc), low PM and high NOx. High rail pressure may result in increased NOx, low PM and slightly improved fuel consumption. A lean air-fuel ratio (AFR), achieved by reducing the total fuel quantity, may result in increased NOx and decreased PM. A rich air-fuel ratio (AFR) achieved by changing the total fuel quantity may result in decreased NOx and increased PM.

FIG. 3 shows a fuel control system 10 for engine 13 based at least partially on engine exhaust 14 emissions. A pedal input 15 may be connected to a speed map 16 for controlling the speed of engine 13 output that may be used for driving a vehicle or some other mechanism. The speed of the engine output 17 may be detected by a speed sensor 18. Sensor 18 may provide an indication 19 of the speed to the speed map 16. The speed map 16 may combine the pedal signal 15 and the speed signal 19 to provide a fuel control signal 21 to a fuel rate limiter, fuel controller or other controller 22.

An NOx sensor 23, situated in exhaust 14, may provide a signal 25 indicating an amount of NOx sensed in exhaust 14. A PM sensor 24 may be situated in the exhaust 14 and provide a signal 26 indicating an amount of PM sensed in exhaust 14. The controller 22 may process signals 21, 25 and 26 into an output signal 27 to an actuator 28, such as a fuel injector and/or other actuator, of engine 13. Signal 27 may contain information relating to engine 13 control such as timing of fuel provisions, quantities of fuel, multiple injection events, and so forth. Signal 27 may go to an engine control unit 26, which in turn may sense and control various parameters of engine 11 for appropriate operation. Other emissions sensors, such as SOx sensors, may be utilized in the present system 10 for fuel control, emissions control, engine control, and so forth.

Fuel injection systems may be designed to provide injection events, such as the pre-event 35, pilot event 36, main event 37, after event 38 and post event 39, in that order of time, as shown in the graph of injection rate control in FIG. 2. After-injection and post-injection events 38 and 39 do not contribute to the power developed by the engine, and may be used judiciously to simply heat the exhaust and use up excess oxygen. The pre-catalyst may be a significant part of the present process because all of the combustion does not take place in the cylinder.

In FIG. 3, signals 25 and 26 may indicate NOx and PM amounts in exhaust 14 to the fuel rate limiter, fuel controller or controller 22. The controller 22 may attempt to adjust or control fuel injection or supply, and/or other parameter, to the engine 13 so as to control or limit the NOx and PM emissions in the exhaust 14. The emissions may be maintained as represented by a portion 31 of the curve 11 in FIG. 1. The tradeoff between NOx and PM typically means that a reduction in PM may be accompanied by an increase in NOx and vice versa. The PM sensor 24 may be relied on for information at portion 32 of curve 11. The NOx sensor 23 may be relied on for sensing information at portion 33 of curve 11. Both sensors 23 and 24 may provide information in combination for attaining an emissions output of the exhaust 14 in the portion 31 of curve 11.

The PM sensor 24 may appropriately characterize the PM portion 32 of the curve 11 which typically may be associated for example with a rich combustion or a high exhaust recirculation rate. The NOx sensor 23 may be better suited to characterize the other extreme of the combustion which typically may be associated for example with a lean or hot burn and a low exhaust combustion rate.

In some cases, the controller 22 may be a multivariable model predictive Controller (MPC). The MPC may include a model of the dynamic process of engine operation, and provide predictive control signals to the engine subject to constraints in control variables and measured output variables. The models may be static and/or dynamic, depending on the application. In some cases, the models may produce one or more output signals $y(t)$ from one or more input signals $u(t)$. A dynamic model typically contains a static model plus information about the time response of the system. Thus, a dynamic model is often of higher fidelity than a static model.

In mathematical terms, a linear dynamic model has the form:

$$y(t) = B_0 * u(t) + B_1 * u(t-1) + \dots + B_n * u(t-n) + A_1 * y(t-1) + \dots + A_m * y(t-m)$$

where $B_0 \dots B_n$, and $A_1 \dots A_m$ are constant matrices. In a dynamic model, $y(t)$ which is the output at time t , may be based on the current input $u(t)$, one or more past inputs $u(t-1), \dots, u(t-n)$, and also on one or more past outputs $y(t-1) \dots y(t-m)$.

A static model may be a special case where the matrices $B_1 = \dots = B_n = 0$, and $A_1 = \dots = A_m = 0$, which is given by the simpler relationship:

$$y(t) = B_0 u(t)$$

A static model as shown is a simple matrix multiplier. A static model typically has no "memory" of the inputs $u(t-1), u(t-2) \dots$ or outputs $y(t-1) \dots$ and the like. As a result, a static model can be simpler, but may be less powerful in modeling some dynamic system parameters.

For a turbocharged diesel system, the system dynamics can be relatively complicated and several of the interactions may have characteristics known as "non-minimum phase". This is a dynamic response where the output $y(t)$, when exposed to a step in input $u(t)$, may initially move in one direction, and then turn around and move towards its steady state in the opposite direction. The soot (PM) emission in a diesel engine is just one example. In some cases, these dynamics may be important for optimal operation of the control system. Thus, dynamic models are often used, at least when modeling some control parameters.

In one example, the MPC may include a multivariable model that models the effect of changes in one or more actuators of the engine (e.g., fueling rate, and the like) on each of one or more parameters (e.g., engine speed 19, NOx 26, PM 25), and the multivariable controller may then control the actuators to produce a desired response in the two or more parameters. Likewise, the model may, in some cases, model the effects of simultaneous changes in two or more actuators on each of one or more engine parameters, and the multivariable controller may control the actuators to produce a desired response in each of the one or more parameters.

For example, an illustrative state-space model of a discrete time dynamical system may be represented using equations of the form:

$$x(t+1) = Ax(t) + Bu(t)$$

$$y(t) = Cx(t)$$

The model predictive algorithm involves solving the problem:

$$u(k) = \arg \min \{J\}$$

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Where the function J is given by,

$$J = \hat{x}(t + N_y | t)^T P \hat{x}(t + N_y | t) + \sum_{k=0}^{N_y-1} [\hat{x}(t+k | t)^T Q \hat{x}(t+k | t) + u(t+k)^T R u(t+k)]$$

Subject to Constraints

$$y_{min} \leq \hat{y}(t+k | t) \leq y_{max}$$

$$u_{min} \leq u(t+k) \leq u_{max}$$

$$x(t) = x(t)$$

$$\hat{x}(t+k+1 | t) = A \hat{x}(t+k | t) + B u(t+k)$$

$$\hat{y}(t+k | t) = C \hat{x}(t+k | t)$$

In some examples, this is transformed into a quadratic programming (QP) problem and solved with standard or customized tools.

The variable “y(k)” may contain the sensor measurements (for the turbocharger problem, these include but are not limited to engine speed, NOx emissions, PM emissions, and so forth). The variables $\hat{y}(k+t | t)$ denote the outputs of the system predicted at time “t+k” when the measurements “y(t)” are available. They may be used in the model predictive controller to choose the sequence of inputs which yields the “best” (according to performance index J) predicted sequence of outputs.

The variables “u(k)” are produced by optimizing J and, in some cases, are used for the actuator set points. For the fuel controller problem these signals 27 may include, but are not limited to, the timing, quantity, multiple injection events, and so forth. The variable “x(k)” is a variable representing an internal state of the dynamical state space model of the system. The variable $\hat{x}(t+k | t)$ indicates the predicted version of the state variable k discrete time steps into the future and may be used in the model predictive controller to optimize the future values of the system.

The variables y_{min} and y_{max} are constraints and may indicate the minimum and maximum values that the system predicted measurements $\hat{y}(k)$ are permitted to attain. These often correspond to hard limits on the closed-loop behavior in the control system. For example, a hard limit may be placed on the PM emissions such that they are not permitted to exceed a certain number of grams per second at some given time. In some cases, only a minimum y_{min} or maximum y_{max} constraint is provided. For example, a maximum PM emission constraint may be provided, while a minimum PM emission constraint may be unnecessary or undesirable.

The variables u_{min} and u_{max} are also constraints, and indicate the minimum and maximum values that the system actuators $\hat{u}(k)$ are permitted to attain, often corresponding to physical limitations on the actuators. For example, the fuel quantity may have a minimum value and a maximum value corresponding to the maximum fuel rate achievable by the actuator. Like above, in some cases and depending on the circumstances, only a minimum u_{min} or maximum u_{max} constraint may be provided. Also, some or all of the constraints (e.g. y_{min}, y_{max}, u_{min}, u_{max}) may vary in time, depending on the current operating conditions. The state and actuator constraints may be provided to the controller 22 via an interface.

The constant matrices P, Q, R are often positive definite matrices used to set a penalty on the optimization of the

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respective variables. These may be used in practice to “tune” the closed-loop response of the system.

FIG. 4 is a schematic view of an illustrative model predictive controller. In this example, the MPC 22 may include a state observer 41 and a MPC controller 42. The MPC Controller 84 provides a number of control outputs “u” to actuators or the like of the engine 13. Illustrative control outputs 27 include, for example, the timing, quantity, multiple injection events, and so forth. The MPC controller may include a memory for storing past values of the control outputs u(t), u(t-1), u(t-2), and the like.

The state observer 41 may receive a number of inputs “y”, a number of control outputs “u”, and a number of internal variables “x”. Illustrative inputs “y” include, for example, the engine speed signal 19, the NOx sensor 23 output 26, and/or the PM sensor 24 output 25. It is contemplated that the inputs “y” may be interrogated constantly, intermittently, or periodically, or at any other time, as desired. Also, these input parameters are only illustrative, and it is contemplated that more or less input signals may be provided, depending on the application. In some cases, the state observer may receive present and/or past values for each of the number of inputs “y”, the number of control outputs “u”, and a number of internal state variables “x”, depending on the application.

The state observer 41 may produce a current set of state variables “x”, which are then provided to the MPC controller 42. The MPC controller 42 may then calculate new control outputs “u”, which are presented to actuators or the like on the engine 13. The control outputs “u” may be updated constantly, intermittently, or periodically, or at any other time, as desired. The engine system 44 may operate using the new control outputs “u”, and produces new inputs “y”.

In one illustrative example, the MPC 22 may be programmed using standard quadratic programming (QP) and/or linear programming (LP) techniques to predict values for the control outputs “u” so that the engine system 44 produces inputs “y” that are at a desired target value, within a desired target range, and/or do not violate any predefined constraints. For example, by knowing the impact of the fuel quantity and timing, on the engine speed, NOx and/or PM emissions, the MPC 22 may predict values for the control outputs 27 fuel quantity and timing so that future values of the engine speed 19, NOx 24 and/or PM 23 emissions are at or remain at a desired target value, within a desired target range, and/or do not violate current constraints.

The MPC 22 may be implemented in the form of online optimization and/or by using equivalent lookup tables computed with a hybrid multi-parametric algorithm. Hybrid multi-parametric algorithms may allow constraints on emission parameters as well as multiple system operating modes to be encoded into a lookup table which can be implemented in an engine control unit (ECU) of an engine. The emission constraints may be time-varying signals which enter the lookup table as additional parameters. Hybrid multi-parametric algorithms are further described by F. Borrelli in “Constrained Optimal Control of Linear and Hybrid Systems”, volume 290 of Lecture Notes in Control and Information Sciences, Springer, 2003, which is incorporated herein by reference.

Alternatively, or in addition, the MPC 22 may include one or more proportional-integral-derivative (PID) control loops, one or more predictive constrained control loops—such as a Smith predictor control loop, one or more multiparametric control loops, one or more multivariable control loops, one or more dynamic matrix control loops, one or more statistical processes control loop, a knowledge based expert system, a neural network, fuzzy logic or any other suitable control

mechanism, as desired. Also, the MPC may provide commands and/or set points for lower-level controllers that are used to control the actuators of the engine. In some cases, the lower level controllers may be, for example, single-input-single-output (SISO) controllers such as PID controllers.

The PM sensor **24** may have a spark-plug-like support **62** as shown in FIG. **5**. The PM sensor may provide an output based on the PM formed on the probe. The sensor or probe may be placed in a path of the exhaust of the engine **13**. The length **63** and diameter **64** of a probe electrode **65** may vary depending on the parameters of the sensing electronics and the engine. The probe electrode **65** may be passivated with a very thin conductive coating or layer **66** on it. This coating or layer **66** may prevent electrical shorting by the soot layer accumulated by the probe during the operation of engine **13**. The passivation material **66** may be composed of SiN₄, cerium or other oxide, and/or the like. The thickness of the passivation layer **66** on the probe electrode **65** may be between 0.001 and 0.020 inch. A nominal thickness may be about 0.01 inch. The passivation layer **66** may be achieved with the probe electrode **65** exposed to high exhaust temperatures or may be coated with a layer via a material added to the engine's fuel.

Sensor or probe **24** may have various dimensions. Examples of an electrode **65** length dimension **63** may be between 0.25 and 12 inches. A nominal value of the length **63** may be about 3 to 4 inches. Examples of a thickness or diameter dimension **64** may be between 1/32 inch and 3/8 inch. A nominal thickness may be about 1/8 inch.

An example of the probe may include a standard spark plug housing **62** that has the outside or ground electrode removed and has a 4 to 6 inch metal extension of about 1/8 inch thickness or diameter welded to a center electrode. The sensor **24** may be mounted in the exhaust stream near an exhaust manifold or after a turbocharger, if there is one, of the engine **13**. The sensing electrode **65** may be connected to an analog charge amplifier of a processing electronics. The charge transients from the electrode **65** of probe **24** may be directly proportional to the soot (particulate) concentration in the exhaust stream. The extended electrode **65** may be passivated with a very thin non-conducting layer **66** on the surface of the electrode **65** exposed to the exhaust gas of the engine **13**. For an illustrative example, a 304 type stainless steel may grow the passivating layer **66** on the probe electrode **65** spontaneously after a few minutes of operation in the exhaust stream at temperatures greater than 400 degrees C. (750 degrees F.). However, a passivating layer **66** of cerium oxide may instead be grown on the probe electrode **65** situated in the exhaust, by adding an organometallic cerium compound (about 100 PPM) to the fuel for the engine **13**.

Other approaches of passivating the probe or electrode **65** with a layer **66** may include sputter depositing refractory ceramic materials or growing oxide layers in controlled environments. Again, the purpose of growing or depositing the passivating layer **66** on electrode **65** situated in the exhaust is to prevent shorts between the electrode and the base of the spark-plug like holder **62** due to PM buildups, so that sensor or probe **24** may retain its image charge monitoring activity of the exhaust stream. If the electrode **65** did not have the passivating layer **66** on it, probe **24** may fail after a brief operating period because of an electrical shorting of the electrode **65** to the support base **62** of the sensor due to a build-up of soot or PM on the electrode.

In summary, the controller may have one or more look-up tables (e.g., incorporating a multi-parametric hybrid algorithm), time-varying emission control restraints, proportional-integral-derivative (ND) control loops, predictive con-

strained control loops (e.g., including a Smith predictor), multi-parametric control loops, model-based predictive control loops, dynamic matrix control loops, statistical processes control loops, knowledge-based expert systems, neural networks, and/or fuzzy logic schemes.

In the present specification, some of the matter may be of a hypothetical or prophetic nature although stated in another manner or tense.

Although the invention has been described with respect to at least one illustrative example, many variations and modifications will become apparent to those skilled in the art upon reading the present specification. It is therefore the intention that the appended claims be interpreted as broadly as possible in view of the prior art to include all such variations and modifications.

What is claimed is:

1. An engine controller for controlling at least part of an engine of a vehicle, the engine controller comprising:
 - two or more inputs for receiving two or more different sensor input signals from two or more different engine sensors;
 - one or more outputs for providing one or more control signals to one or more actuators that control one or more inputs to the engine, wherein each of the one or more inputs to the engine has an effect on the two or more sensor input signals from the two or more engine sensors; and
 - a controller configured to receive the two or more different sensor input signals from the two or more different engine sensors and to provide the one or more control signals to the one or more actuators via the one or more outputs, the controller configured to adjust the one or more actuators of the engine to achieve a predicted response in each of the two or more different sensor input signals such that a performance index that references the predicted response of each of the two or more different sensor input signals is optimized.
2. The engine controller of claim 1, wherein the controller is configured to adjust the one or more actuators of the engine to achieve the predicted response in each of the two or more sensor input signals using a multi-parameter model, wherein the multi-parameter model models the effects of changes in the one or more actuators on each of the two or more sensor input signals.
3. The engine controller of claim 1, wherein:
 - the two or more sensor input signals from the two or more engine sensors includes an engine emission sensor input signal; and
 - the one or more control signals effecting a change in one or more fuel properties of a fuel injection event.
4. The engine controller of claim 3, wherein the one or more fuel properties that are affected by the one or more control signals include a fuel injection quantity.
5. The engine controller of claim 3, wherein the one or more fuel properties that are affected by the one or more control signals include a fuel injection event start time.
6. The engine controller of claim 3, wherein the one or more fuel properties that are affected by the one or more control signals include a post fuel injection event start time.
7. The engine controller of claim 3, wherein the one or more fuel properties that are affected by the one or more control signals include a pre fuel injection event start time.
8. The engine controller of claim 3, wherein the one or more fuel properties that are affected by the one or more control signals include a pilot fuel injection event start time.

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9. The engine controller of claim 3, wherein the one or more fuel properties that are affected by the one or more control signals include an after fuel injection event start time.

10. The engine controller of claim 3, wherein one of the one or more fuel properties that are affected by the one or more control signals is a fuel rail pressure.

11. The engine controller of claim 1, wherein the controller includes one or more predictive control loops.

12. The engine controller of claim 11, wherein the one or more predictive control loops include one or more constraints.

13. An engine controller for controlling at least part of an engine of a vehicle, the engine controller comprising:

one or more inputs for receiving one or more sensor input signals from one or more engine sensors, wherein at least one of the one or more sensor input signals includes an engine emission sensor input signal from an engine emissions sensor;

one or more outputs for providing one or more control signals to the engine to control one or more inputs to the engine, wherein each of the one or more inputs to the engine has an effect on each of the one or more sensor input signals, including the at least one engine emission sensor input signal; and

a controller configured to receive the one or more sensor input signals from the one or more engine sensors and to provide the one or more control signals via the one or more outputs to effect a change in one or more fuel properties of a fuel injection event of the engine to achieve a predicted response in one or more of the sensor input signals and the engine emission sensor input signal, wherein a predicted response of the one or more control signals on the engine emission sensor input signal is opposite in sign to a predicted response of the one or more control signals on a different one of the one or more sensor input signals.

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14. The engine controller of claim 13, wherein the one or more fuel properties that are affected by the one or more control signals include a fuel injection quantity.

15. The engine controller of claim 13, wherein the one or more fuel properties that are affected by the one or more control signals include a fuel injection event start time.

16. The engine controller of claim 13, wherein the one or more fuel properties that are affected by the one or more control signals include a post fuel injection event start time.

17. The engine controller of claim 13, wherein one of the one or more fuel properties that are affected by the one or more control signals is a fuel rail pressure.

18. An apparatus, comprising:

a memory storing a control algorithm for an engine controller, the control algorithm comprising:

two or more input parameters for representing two or more engine sensor input signals;

one or more output parameters for representing one or more control signals, the one or more control signals for controlling one or more actuators of an engine that control one or more inputs to the engine, wherein each of the one or more inputs to the engine has an effect on each of the two or more engine sensor input signals; and

a model configured to receive the two or more sensor input parameters and to provide the one or more output parameters, wherein the output parameters are configured to adjust the one or more actuators of the engine to keep a predicted response in each of the two or more sensor input signals within a corresponding predetermined range of values.

19. The apparatus of claim 18, wherein at least one of the engine sensor input signals correspond to an emission sensor.

20. The apparatus of claim 19, wherein the one or more actuators of the engine include a fuel injection actuator.

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